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BUILDING CONSTRUCTION

A TEXT-BOOK OUTLINE

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BUILDING CONSTRUCTION

A TEXT-BOOK OUTLINE

PREPARED by a Sub-Committee of the Educational Committee of The Insurance Institute of America, consisting of Messrs. Gorham Dana, Manager of The Underwriters' Bureau of New England, *Chairman;* Joseph B. Finnnegan of the Armour Institute of Technology, Chicago, and Frederick C. Moore, Assistant Secretary of the Hartford Fire Insurance Company.

Second Edition

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110 WILLIAM STREET
NEW YORK CITY

1924

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CONTENTS

INTRODUCTION

In the pages which follow will be found a brief descriptive outline of BUILDING CONSTRUCTION as required in the Junior or First Year of the Fire Branch of the courses of The Insurance Institute of America. A word of explanation may be necessary as showing the purpose of this outline and the uses to which it is expected it will be put.

Experience has demonstrated the necessity of a definition of the scope of the courses of the Institute. Without it lecturers and students preparing in different localities for the examinations of the Institute are frequently at a loss to know what topics should be included in their preparation.

This outline removes in so far as may be possible such doubt and uncertainty, and establishes in their places a measure of certainty. It shows what is included in the Institute's course in BUILDING CONSTRUCTION, but it does not of itself afford a sufficient basis of study for the passing of the Institute's examinations. It suggests the things concerning which candidates for examination should have some knowledge and indicates the sources from which a requisite knowledge may be obtained.

Students are cautioned not to confine their reading to the outline alone, but in every case to read the specific references cited in the text. Besides the specific references is a list of general references covering the subject as a whole; these should be consulted unless the student is already familiar with their contents.

In preparing questions for examinations, the Educational Committee will ask of the student nothing con-

cerning which sufficient information may not be had by the intelligent use of this outline.

Lecturers will find their work facilitated by a careful examination of the Text-Book Outline, and the appended references.

While they will very properly use their discretion in selecting material for class-room discussion, it is to be hoped that they will keep always in mind the scope of the course as here defined, and especially the comparative emphasis to be laid upon various parts of the subject as indicated on page 52.

Signed,

L. N. DENNISTON, *Chairman,*
Educational Committee.

November, 1923.

These notes have been revised and enlarged by the same committee who prepared the original notes in 1916.

INSURANCE INSTITUTE OF AMERICA

A Text-Book Outline for Junior or First Year Course on Building Construction

(For explanation of references see page 52)

Property insured against fire is to a large extent housed in buildings. *Exceptions*—Lumber yards, ships, goods in transit.

The better the building the less chance for serious loss other things being equal. The usual forms of construction, except standard fireproof construction, with external openings properly protected, are subject to practically complete destruction by fire.

CLASSIFICATION OF BUILDINGS

Frame or Third Class.—Buildings constructed entirely of wood.

Ordinary or Second Class.—Buildings constructed with external walls of masonry. Interior floors and roof of wood or combustible material.

Fireproof or First Class.—Buildings constructed practically of fireproof material throughout. Wood allowed only for under and upper flooring, windows and door

frames, sashes, doors, interior finish, hand rails for stairs, sleepers embedded in cement and furring embedded in cement. No air space allowed between floor arch and floor boarding.

Mill Construction.—A building with masonry walls and plank and timber floors. All stairs and elevators cut off in masonry towers. A superior second class building.

DEFINITIONS

A number of terms are used in building construction in a special way and a clear understanding of these is necessary. Reference is made to the National Board of Fire Underwriters' Building Code and to the other pages in this pamphlet for definitions of some of these such as balloon frame, basement, bay, bearing wall, braced frame, brick nogged, brick veneer, cellar, corbel, curtain board, cut off, factory, furring, header, hotel, lantern (or monitor), lintel, louvre, mezzanine, mullion, muntin, parapet, party wall, pilaster, pintle, purlin, skewback, Texas, theatre, valley, wall plate, workshop.

BUILDING MATERIALS

(*See Dwelling Houses, Pages* 17-21. *Building Code Pages* 78-84.)

Bricks of good quality are the best fire resisting material. Used extensively for walls, occasionally for floors. Bricks are porous and absorb water readily. They should be thoroughly wet before laying so as not to suck water out of the mortar and thus weaken it. Bricks are lighter than stone and are less affected by fire and water. They should be carefully laid in cement and lime mortar. Fire brick, made for construction of furnaces, etc., will withstand temperatures over 2200° F.

Concrete.—Is made by mixing cement, sand, broken stone or cinders, and water. It has high compressive but

low tensile strength. When tensile strength is needed, it must be reinforced with steel members.

Concrete is a satisfactory building material but will calcine or dehydrate on the surface and spall under intense heat. All reinforcing material should therefore be covered with a sufficient thickness of concrete. Used for walls, roofs, floors, girders, posts and foundations. Hollow or solid concrete blocks are sometimes used for wall construction but they vary greatly as to quality.

Hollow Tile or Terra Cotta is made from a moist mixture of clays with ground terra cotta previously burned. It is moulded into shape and burned at a temperature of 2000 to 2500° F. Porous terra cotta is made by mixing sawdust with the clay, this being burned out later.

Hollow Tile is a good fire resisting material but varies greatly as to quality. Used for floors, roofs, partitions and sometimes for walls of steel frame buildings. Under high temperature it frequently splits on account of unequal expansion of the face and ribs. It also sometimes breaks away from its supporting members on account of not being supported in a manner to overcome the strains due to expansion.

Stone.—Most stone will spall under intense heat and some stone like granite will disintegrate. Marble and other limestones will calcine and become powdery. Used for walls and foundations.

Sharp angles of stone such as window lintels are especially subject to spalling.

Cast Iron is noncombustible and has great compressive but small tensile strength. It is not used as much as formerly. Used for columns and occasionally for front surface of buildings. It will crack under high temperature especially if subjected to hose streams. It is also liable to become deformed and even to shear under severe conditions.

Steel.—This is replacing cast iron for columns and is very extensively used in fireproof construction.

Steel will soften and collapse under high temperature and will lose much strength at comparatively moderate temperatures. It should therefore be covered with an insulating material such as brick, tile or concrete. Used for columns, girders and all sorts of built-up framing. Corrugated sheet steel is used for non-bearing walls.

Wood.—Wood is the most common building material —at least in this country—and is very combustible. It does not expand however when heated and will not buckle, soften or spall. When in large masses, as in plank and timber floors, it will withstand a hot fire for a long time. A heavy wood post is preferable from a fire protection point to one of unprotected iron or steel. Wood rots when wet and dried alternately, but wood kept continuously wet or continuously dry will last indefinitely. An exception to this statement must be made in the case of dry rot which is a fungus growth occurring especially where there is a damp atmosphere. It can be prevented by antiseptic treatments such as immersion in a bath of corrosive sublimate; and to some extent by boring a hole in the center of a large timber and venting each end with a smaller hole. Dry rot generally takes place unnoticed until it has reached a point where the strength of the timber is greatly affected.

(*See pamphlet on Dry Rot—Associated Factory Mutual Insurance Co.*)

A very desirable wood for heavy timbers is best quality Southern pine, long leaf slow growing, containing a large percentage of resin. Short leaf pine known as Loblolly has less resin and is more susceptible to fungus growth. Douglas fir is now largely used and is practically non-resinous.

Wood can be "fireproofed," or more properly, rendered less ignitable, by impregnating it with certain salts, notably sulphate of alumina, phosphate of ammonia, and sulphate of ammonia. This is expensive and is seldom done at present. (*See N. F. P. A. Proceedings* 1901, *Pg.* 64.)

Fire retardant paints are of slight value in making wood less easily ignited. These are generally of the dry powder and water variety but whitewash made by the U. S. Government formula is probably as good as most of these.

Other materials of less importance are the following: gypsum blocks, made of plaster of Paris; Lally columns, made of hollow steel filled with concrete; asbestos lumber, made of asbestos fibre and cement; various wall boards made of gypsum plaster or cement, in connection with wood pulp and sometimes clay; and metal lath.

FOUNDATIONS

(*National Board Building Code, Pages* 25-34. *Dwelling House Code, Pages* 21-24.)

Foundations may be of concrete, stone or brick. They should extend below frost line. They should be figured according to the conditions of the soil and the load to be carried. If bearing pressures are not properly proportioned, unequal settlement occurs. There is then danger of opening cracks in walls, flues, and other parts of the structure.

Bearing pressures on average soil may be figured at 2 to 4 tons per square foot. On soft clay 1 ton per square foot. Hard pan may run 8 to 15 tons and rock 15 tons up.

Piles, etc.—In very soft soil, piles may be necessary. These may be of wood or concrete. If of wood the tops should be cut off below mean low water level to prevent rot. If of concrete they may be cast before placing or cast

in place. When very high buildings are to be built or where the soil is especially poor, special methods, such as grillage or caissons are necessary.

Mortar.—Mortar is generally made of cement, lime, and sand. Cement mortar is stronger than lime mortar but a little lime is desirable. Mortar should provide a uniform and complete bearing for each stone or brick and should also bind them together.

Lime is made by roasting limestone. It is not hydraulic and must be kept dry to set.

Natural Cement such as Roman and Rosendale is made by roasting cement rock containing principally silica, alumina, iron oxide, calcium oxide, magnesium oxide, etc. It has been almost entirely replaced in the market by Portland cement.

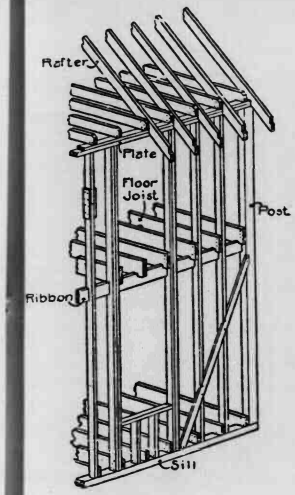
Portland Cement, named from its resemblance to Portland stone, contains similar chemical ingredients to natural cement but in different proportions. Slag from blast furnaces is used in its composition. It is highly hydraulic, that is it will harden or "set" under water. (*See N. F. P. A. Quarterly, July,* 1908, *Page* 35, *and Building Construction by Kidder.*)

FRAME CONSTRUCTION

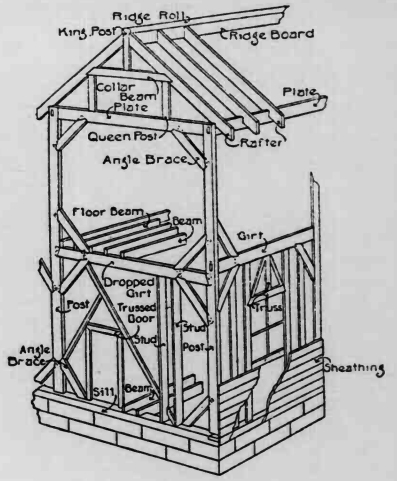
(*See Building Code, Pages* 186-191.)

In this type both walls and floors are of wood. Walls may be "braced" or "balloon" frame.

Braced Frame.—In this type (sometimes called full frame) a sill consisting of a timber 4 x 5 inches or larger rests on the foundation. Wall studs are spiked or morticed to the sill. At the second floor level, a floor girt is inserted which is similar to the sill. Corner posts are braced to the sill and floor girt. At the eaves the girt is called a plate. Dropped girts are installed to support the



Balloon Frame



Braced or Full Frame

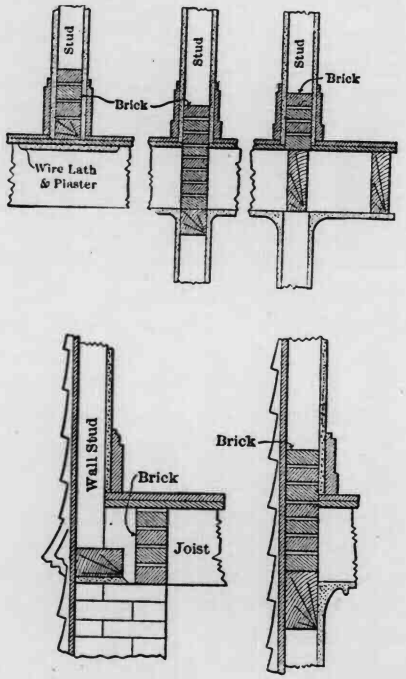
other end of floor joists to keep them level. Floor joists rest on girts and plates.

Balloon Frame.—In a balloon frame there are no girts but the posts and studs run from the sill to the plate of the building. This gives a weaker frame and one in which fire is more likely to spread from floor to floor inside the hollow wall. This type is prohibited in some building codes.

Details.—Studs are of rough lumber 2 x 4 inches or larger and spaced 16 to 24 inches apart. Girts are 4 x 6 inches or larger. Joists and rafters are 2 x 8 inches or larger. Floors are generally double board, the boards in each layer running in a different direction. Cross bracing is necessary for floor joists and for studs to make a stiff structure.

Finish.—Interior finish and roofs are similar to those in second class construction. Walls are generally finished on the outside with boarding either horizontally or at an angle of 45 degrees and with a wearing surface generally of clapboards, or shingles. It is desirable to place building paper under the shingles or clapboards.

Brick Veneer may be installed instead of clapboards or shingles and consists of a wearing surface of brick usually 4 inches thick. This is but little better than frame except as a protection against exposure.



Methods of stopping off hollow space in walls at floor level

Brick filled or brick nogged construction is frame or third class with bricks filled in between the studs on the inside. This reduces to a minimum the hazard of fire spreading from floor to floor through hollow walls.

Frame buildings are also frequently covered with cement or stucco, which, if well done, is a considerable protection against exposure.

Height and Area.—Height should not exceed 3 stories or 45 feet. Area should not exceed 5000 sq. ft. unless sprinklered. Distance apart of frame buildings should be at least 10 feet.

ORDINARY OR NON-FIREPROOF CONSTRUCTION

(*See Building Code, Pages* 34-42, *also Pages* 97-102)

Walls.—In this construction the non-combustible walls should be thick enough to support the load properly and except in 1 story buildings should be at least 12 inches thick. They should preferably be built in such a way that the floors can be supported on ledges, which may be formed by corbelling out from a smooth wall or by making the walls at each floor thinner than at the floor below. (*See Building Code, Page* 38.)

Hangers are sometimes mounted in the wall to carry the ends of the floor joists. Walls may be of equal thickness throughout each floor or may consist of pilasters and curtain walls.

Floors.—Floors consist of joists usually about 3 x 12 inches in size spaced approximately 16 inches apart and properly braced. These are supported by the wall or by girders resting on posts. The floor is nailed on the joists and consists preferably of two layers of boards, a rough under floor and a finished wearing surface. It is well to place a building paper, preferably waterproof, between the two floors.

The under side of the joists may be left open finish or may be sheathed in some way. (*See Section on Interior Finish.*)

Partitions.—Interior partitions are generally sheathed in a similar manner. The uprights in such partitions are called studs and are generally spaced 12 inches to 18 inches apart. They are braced together about half way up.

Posts may be wood, cast iron or steel.

Roofs.—Roof may be flat or peaked. If flat there is but a slight pitch to give drainage and it is of similar construction to floors. If peaked the supporting beams are called rafters and the supporting member at the top, the ridge pole. Windows in a sloping roof are called dormers. (*See Section on Roofs and Roofing.*) A mansard roof is one that has but slight slope near the center, but is nearly vertical near the walls. It forms an undesirable feature in a second-class building, especially if there is serious exposure.

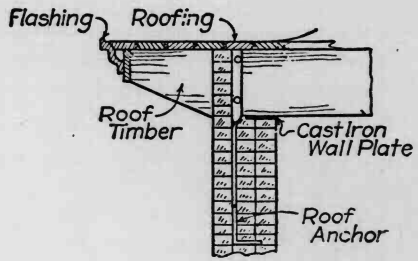
Height, Area, Etc.—Height should not exceed 55 feet or 2½ times the width of street on which it faces. Area should not exceed 5000 square feet unless sprinklered when it may be increased 66 2/3%. When on a street corner a larger area is permissible. Large areas are undesirable on account of the difficulty of fighting fire.

MILL CONSTRUCTION

(*See Building Code, Pages* 123-127 *f, also N. F. P. A. Pamphlet on Mill Construction*)

Mill construction is a modification of ordinary or second-class construction and is important from a fire protection standpoint as it is a much better fire risk. It is seldom found in its perfect form. A sprinklered mill constructed building may be as good a risk and sometimes better than an unsprinklered fireproof building.

The main features are: thick floors, heavy units offering a small surface to fire, self-releasing floor timbers, open finish and thoroughly enclosed floor openings.

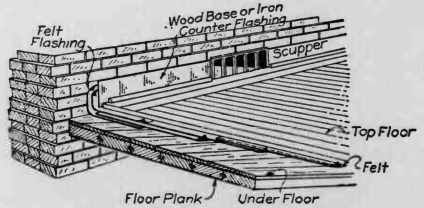


Roof Details, Mill Construction

Walls.—Walls to be brick or concrete less than 12 inches thick at top story and increased at floors below so as to carry the load properly.

Roofs.—Roofs to be plank at least 2½ inches thick on beams or timbers not less than 6 inches in either dimension. Covering to be tar and gravel or equally fire resisting material. Cornices to be open finish.

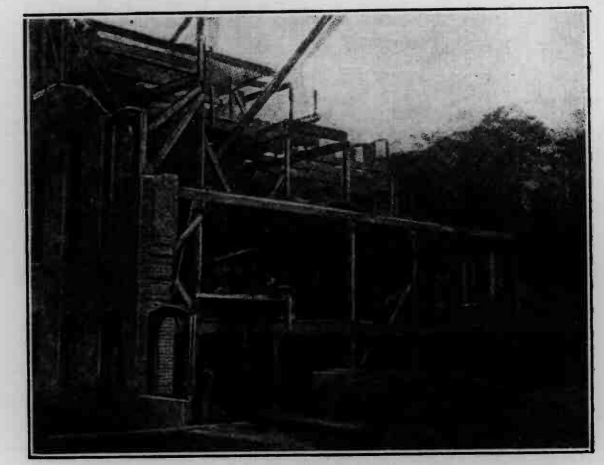
Floors.—Floors to be plank 3 inches or more thick, with 1 inch top floor laid crossways or diagonally and resting on timbers. Laminated floors, that is those made



Floor Details, Mill Construction

of plank on edge spiked together, are also sometimes used. Timbers should be not less than 8 inches in either dimen-

sion. All timbers to be self releasing. This is accomplished by bevelling the end of a beam that rests in the wall to such an extent that if the beam falls it will not break or rupture the wall. Enough space is left around the end of the beam to give good ventilation. At the post end, the timber rests on an iron plate or cap and is attached to the opposite beam by "dogs." Any beam can fall without pulling down the adjoining beam. Water-

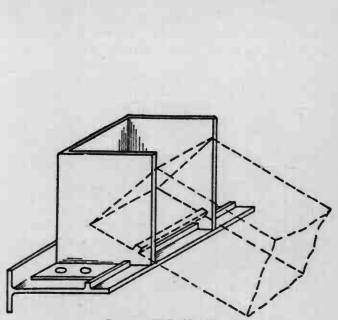


Mill Construction Building

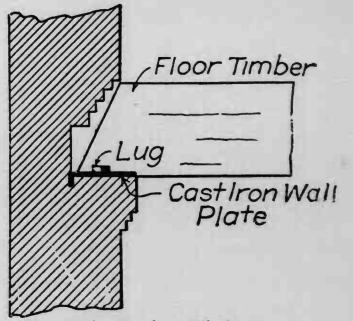
proof material to be placed between plank and top floor. Bays should be 6 to 12 feet wide.

Posts to be timber not less than 8 inches in either dimension. No combustible finish to be used.

Floor Openings.—Stairs, elevators and belt-ways to be cut off in brick shafts, walls being at least 8 inches thick and extending at least 3 feet above roof. All openings in these walls to be protected by standard fire doors, to pre-



Iron Wall Box

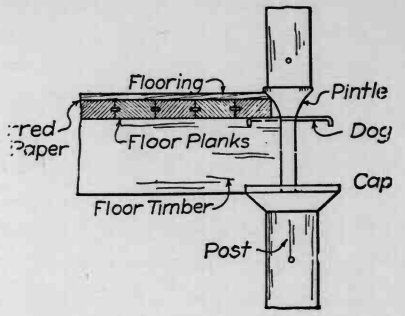


Self-releasing Timbers

Details of Mill Construction

vent spread of fire from one floor to another. It is desirable to place stair and elevator towers entirely outside the building.

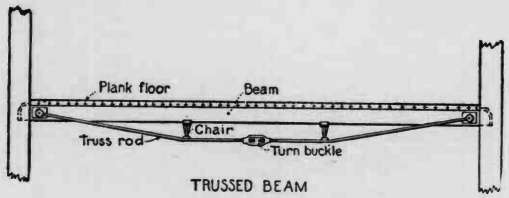
In General.—This type of construction gives minimum combustible surface for any given degree of strength and allows no openings from floor to floor through which fire can spread. It gives chance to use hose streams to best advantage, there being a window in the center of each bay through which fire streams can sweep the entire bay.



Details of Mill Construction Floor

It allows part of floor to fall without endangering other portions and facilitates most effective distribution from automatic sprinklers.

Sub-Standard Features.—Double beams with space between and unprotected steel beams are replacing solid beams to some extent on account of high cost of the latter. They are not so desirable however. Double beams sacrifice the principal of massive members offering minimum surface exposed to fire and also allow fire to get in between the two timbers where it is very difficult to extinguish. Steel beams are satisfactory if properly fireproofed. These are being used on account of the scarcity of heavy timbers.

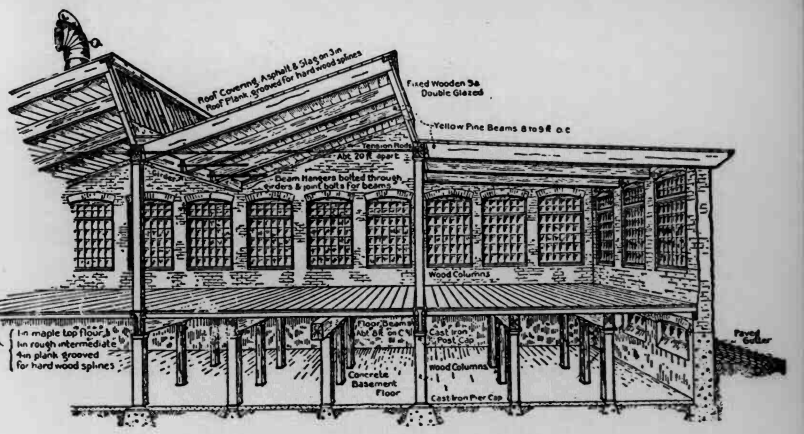


TRUSSED BEAM

Beams covering a long span are sometimes trussed for additional strength. This is very undesirable as metal trusses are apt to expand rapidly under heat and slip off from the chair supports and thus bring the entire load onto the beam.

Semi-mill construction usually refers to a sub-standard type consisting of plank and timbers not in the form of bays 6 to 12 feet wide and often with cross timbers forming pockets.

In the Wilson type, concrete posts and beams are used with plank floors.



Cross Section of Mill Constructed Building

FIREPROOF CONSTRUCTION

(*See Building Code, Pages* 128-163)

The materials commonly used in fireproof construction are concrete, steel, tile and brick. Steel has great tensile as well as compressive strength, but must be protected against heat and corrosion. It is used in the form of girders, beams and built-up columns. Concrete has great compressive but low tensile strength. It is therefore necessary to reinforce it with steel where it is used for other than compressive loads. This steel work must also be properly protected from heat. Tile is used for floors—filling in between beams and girders. Brick was formerly used for floors in the form of arches but tile has replaced it because it is lighter. Brick is now principally used for walls.

In a fireproof building the entire structure should be of fire resisting material except that wood is generally allowed for top flooring, windows, doors, temporary partitions, mop boards, chair rails and other minor finish.

Principal Types of Walls.

A. Brick or masonary walls, carried on their own foundations.

B. Skeleton steel, brick or masonry curtain walls.

C. Reinforced concrete monolith.

D. Combinations of above.

Principal Types of Floors.

1. Brick arch on brick, stone or cast iron supports and columns.
2. Brick arch on steel beams.
3. Terra cotta arches on steel beams.
4. Reinforced concrete on steel beams.
5. Reinforced concrete on reinforced concrete beams.
6. Reinforced concrete mushroom type.
7. Combinations of the above, especially reinforced concrete and terra cotta in steel frame buildings and the "Rib" and "Grid" systems in the concrete mushroom type, the design of both types being to lighten the floor.

Types 1 and 2 are now seldom built on account of the excessive weight and expense. Groined arch construction is of the first type. Guastavino tile arch is a form of groined arch construction occasionally used, especially in public buildings.

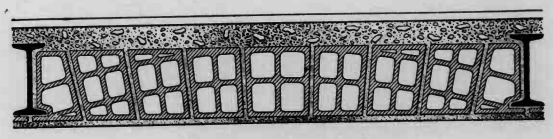
Type 3.—The steel frame has become almost universal for high buildings as it will carry the great weights involved with comparatively small bulk. A very common and desirable type of construction.

In this construction the walls carry little or no weight and are simply curtain walls. The weights are carried

by built up steel columns in the interior and in the walls.

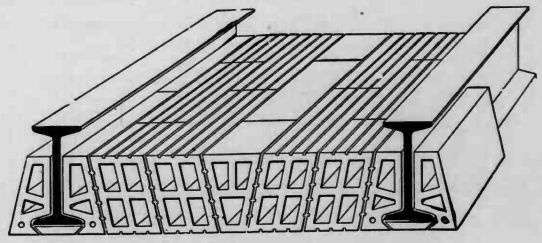
Steel "I" beams are usually the supporting members for floors, these being riveted to the columns and to steel girders. Beams are placed 3 to 8 feet apart.

The tiles resting on the steel beams may be in the form of flat or segmental arches. Where the latter is used a false ceiling is often placed below to give a flat surface. This false ceiling is someimes the only protec-

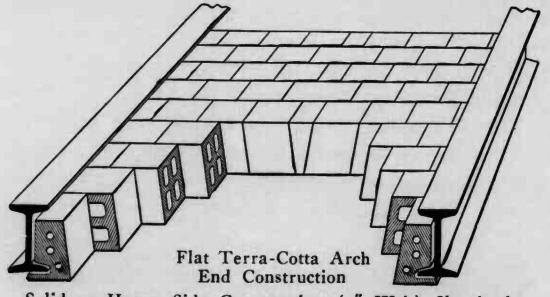


Flat Terra-Cotta Arch
Side Construction, Arched Ribs

tion afforded the lower flanges of the steel I-beams, but is not sufficient for this purpose. Tiles may be laid "side" or "end" construction, the latter being where the hollow spaces in the tile run at right angles to the beams. The end tiles of an arch are called skewbacks and the center tile the key. Where "end" construction is used the skewbacks are generally of "side" construction as they can be made to fit the beam outline better. If the floor was equally loaded the thrust would be the same on each side of the supporting "I" beams. As the load is liable to be



Flat Terra-Cotta Arch
Side Construction



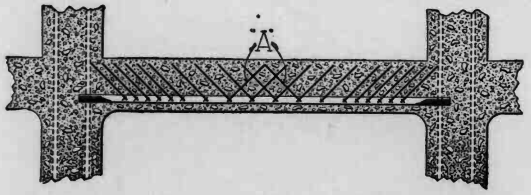
Flat Terra-Cotta Arch
End Construction

Solid or Heavy Side Construction (2″ Web) Skewbacks
Interior Webs 1″ to 1½″ Thick with Well Rounded Angles

unequal, the tie rods are used to hold the "I" beams in place.

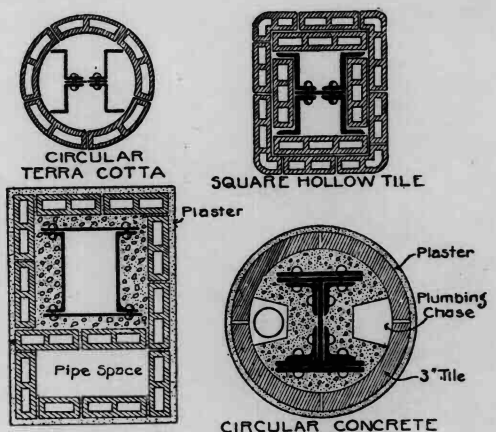
Above the tile, concrete or some form of non-combustible filling is used to make a level surface. If a wooden top floor is to be used, sleepers, preferably trapezoidal in section, to which the boards are nailed, should be embedded in the concrete. There should be no hollow space under the boards, as a fire might travel in such a space, and the dropping even this small distance of such a thing as a safe, makes it likely that the floor arch would be broken through.

All steel members, both in floor and wall supports should be fire proofed with tile, brick or concrete. Columns should be covered to a thickness of at least 3 inches,



Proper Form of Reinforced Concrete Girder or Beam

Full Lines Denote Reinforcing Members for Girder—Dotted Lines Reinforcement for Columns—"A" "A" Shows Reverse Reinforcement—"X" Rods Securely Fastened to Bar

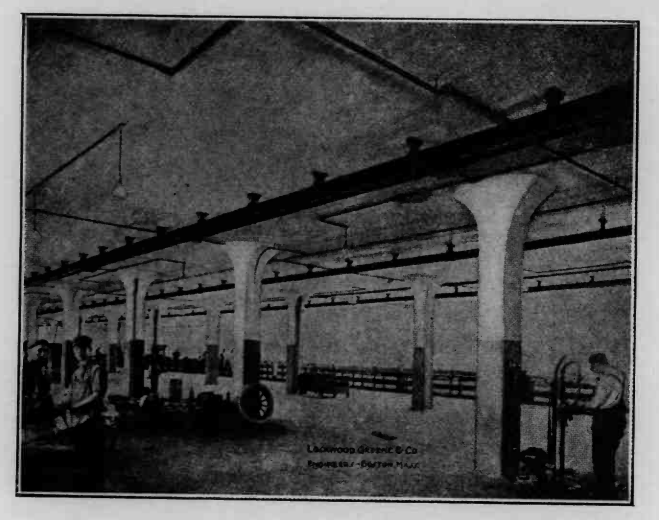


TYPES OF
COLUMN PROTECTION

girders at least 2 inches and beams at least 1½ inches. Under sides of beams and girders should be given special attention. There are several methods of doing this, some of which give poor protection. (*See Building Code, Pages* 132-136.)

Pipes should not be enclosed in the protection around columns in steel frame construction, as in case of fire they may expand faster than the column and break the insulating material; also because in making pipe repairs, fire proofing is not usually properly replaced.

Types 4 and 5.—Reinforced concrete may be used instead of tile to fill in between the I-beams. Various forms of reinforcing material are used, usually twisted or deformed rods which will not readily slip in the concrete. The concrete slab is usually flat with the reinforcing material near the bottom to take the tensile strain. This steel work should be well covered with concrete so as not to be exposed to heat in case of a hot fire.



Interior of Mushroom Type Reinforced Concrete Building

If concrete beams are used instead of steel, they should be reinforced in a similar manner to the floor slab. Concrete in the form of arches sprung between the I-beam can also be used. In either case the I-beam should be protected on all sides by at least 2 inches of concrete.

Type 6.—Mushroom concrete construction consists of a concrete monolith with no steel skeleton. Columns are concrete reinforced with vertical rods tied together at intervals. These rods are bent out like the ribs of an umbrella at the top of each column and tied into the floor reinforcement, which is usually in the form of groups of parallel rods running in several directions. Sometimes it is in the form of large hoops overlapping and wired together at the junctions. All steel work should be properly insulated as in the previous types.

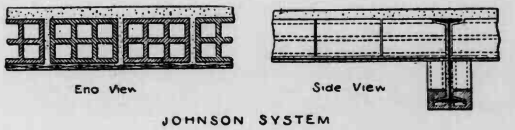
Type 7.—Combinations of tile and concrete are coming into very general use.

The Johnson system consists of tile embedded in concrete. Concrete reinforced with rods interwoven with wire extends under the tiles and a layer of concrete covers them. It has been used for spans up to 25 feet, thus effecting a considerable saving in cost. It is also much lighter than solid concrete.

Another combination in common use is built by spacing the tiles 4 or 5 inches apart with concrete reinforced by rods between and an overlay of concrete. Beams may be either steel protected with tile or may be reinforced concrete. Columns should have 3 inches of fire proofing and main girders 2 inches.

The "Rib" system in the concrete mushroom type is formed by using long metal pans in rows with concrete ribs between, the pans being from 8 inches to 10 inches deep and covered with 2 inches to 3 inches of concrete. The effect of this type after the pans are removed being much the same as an open joisted ceiling.

The "Grid" system is similar except that the pans are square (about 14 inches) and the concrete ribs run both ways.



JOHNSON SYSTEM

COMBINATION FLOOR

Two Types of Combined Tile and Concrete Construction

The disadvantage of these types lies in the fact that a large proportion of the floor is only 2 inches to 3 inches thick.

Mixtures.—Concrete mixture should consist of cement, sand, broken stone and water. Cinders sometimes used instead of stone. This mixture is lighter but more apt to corrode metal that may be in contact with it. Proportions, 1 cement, 2 sand, 3 stone is a rich mixture. One cement, 3 sand, 6 stone is the other extreme. One-two-four is considered a good average.

There should be water enough to make a wet mixture that will quake when tamped. Mixing should be thorough. High grade workmanship is very important. Great care should be taken to thoroughly bond new work to old, also to prevent freezing before cement has thoroughly set and not to remove forms too soon.

ROOFS

(*See Building Code, Page* 102)

Principal types are flat, gable or peak, mansard, gambrel and sawtooth. Monitors are sometimes used on flat roofs. A Texas is a form of monitor. These should not be located near fire walls, because they offer easy entrance

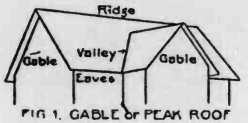


FIG 1. GABLE or PEAK ROOF

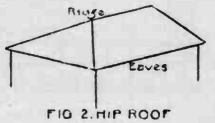


FIG 2. HIP ROOF

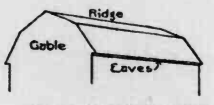


FIG. 3. GAMBREL ROOF.

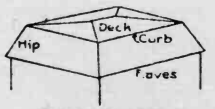


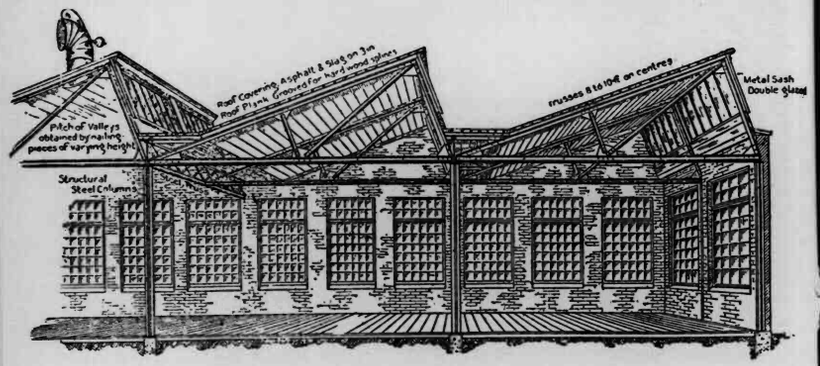
FIG 4. MANSARD or FRENCH ROOF.

TYPES OF ROOFS

Interior View Saw Tooth Roof

to an overlapping flame. Roof structures in general should be of fireproof construction. Roofs supported by unprotected steel trusses are undesirable as they collapse under comparatively slight heat. Fire is hard to fight in long peak roofs. Curtain boards can be used to prevent rapid spread of fire under such roofs. These are tight partitions preferably of non-combustible material extending from peak down several feet preferably to level of eaves. They are especially desirable in sprinklered buildings as they tend to bank up the heat and make the sprinklers operate more promptly.

Flat and sawtooth roofs are preferable to the other types from a fire protection standpoint.



Sections of Mill with Saw Tooth Roof

ROOFING MATERIALS

Underwriters' Laboratories Classification of Roof Coverings: (See Approved List; Roofing Materials)

Class A includes roof coverings which are effective against *severe* fire exposures. Under such exposures roof coverings of this class are not readily flammable and do not carry or communicate fire; afford a fairly high, to a high degree of heat insulation to the roof deck; do not slip from position; possess no flying brand hazard; and do not require frequent repairs in order to maintain their fire resisting properties.

Class A includes the best grades of tar and gravel (or crushed slag); asbestos roof coverings; asbestos shingles, American method; also tile, best grades of slate and tin.

Class B includes roof coverings which are effective against *moderate* fire exposures. Under such exposures roof coverings of this class are not readily flammable and do not readily carry or communicate fire; afford a moderate degree of heat insulation to the roof deck; do not slip from position; possess no flying brand hazard; but may

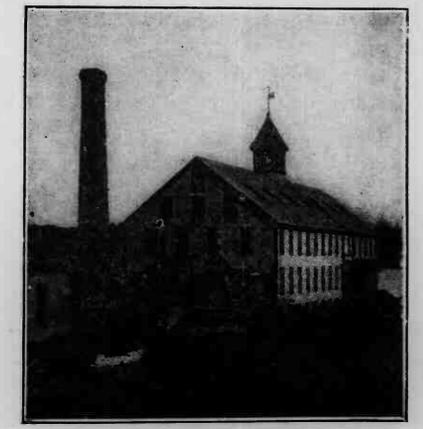
require occasional repairs in order to maintain their fire resisting properties.

Class B includes best grades of asbestos and felt and asbestos shingles, French method.

Class C includes roof coverings which are effective against *light* fire exposure. Under such exposures roof coverings of this class are not readily flammable but may carry and communicate fire; afford at least a slight degree of heat insulation to the roof deck; do not slip from position; may require fairly frequent repairs or renewals in order to maintain their fire resisting properties.

Class C includes many brands of prepared two and three ply asphalted rag felt both in sheet and shingle form. (*See list of approved devices, Underwriters' Laboratories.*)

All inferior types such as the poorer grades of tar paper and all wooden shingles are unapproved. Wooden shingles are a very hazardous roof covering. They will take fire readily from railroad sparks, chimney sparks and



Mill with Peak Roof

all kinds of burning brands. They also create a serious burning brand hazard as they are light and easily become detached from the roof in a serious fire. They have been demonstrated many times to be conflagration breeders.

CHIMNEY AND FIRE PLACE CONSTRUCTION

Chimneys.—(See Building Code, Page 173; *Dwellings, Pages* 52-68; *Chimney Ordinance—National Board of Fire Underwriters.*)

Walls should be of brick or concrete and not less than 8 inches thick unless lined on the inside with well burned terra cotta or fire clay chimney tile; in which case the wall should not be less than 4 inches. Timber framing around chimneys should be at least 2 inches away from brick work.

Brick set on edge should not be permitted.

All chimneys should project at least 3 feet above the point of contact with a flat roof, or 2 feet above the ridge of a pitched roof. They should be properly capped with stone or concrete.

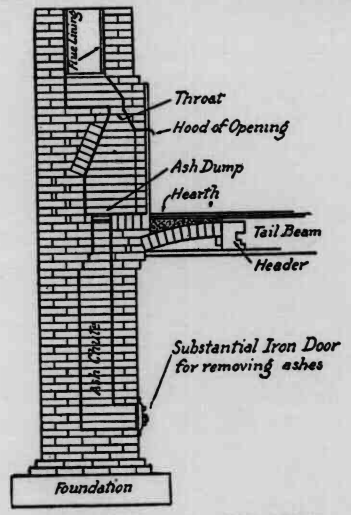
No chimneys should have wooden supports of any kind. Single thickness tile chimneys are unsafe as they are very liable to crack.

Metal smoke stacks may be permitted for boilers, furnaces and similar apparatus, provided they have a clearance from all combustible material of not less than one-half the diameter of the stack, but never less than 9 inches. Where stack passes through a roof it should be guarded by a galvanized iron ventilating thimble.

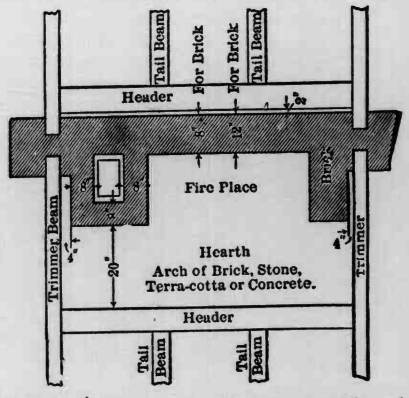
Metal stacks should not pass through a floor.

Fire Places and Stoves. (See Building Code, Pages 177 *and* 180.)

No woodwork should be within 4 inches of the back wall of any fire place.



Section of Chimney and Fire Place



Plan Showing Proper Framing Around Fire Place

Tile Chimney Showing Cracks

The header beam, carrying the tail beams of a floor and supporting the trimmer arch in front of a fire place, should be not less than 20 inches from the chimney brest.

No wooden furring or studding should be placed against a chimney. (*See Building Code, Pages* 99-101.)

No smoke pipe should be within 9 inches of any woodwork, or any wooden plaster partition, or ceiling. Where passing through combustible partitions, metal collars of proper size should be used.

Smoke pipes should not pass through floors or combustible roof. (*See Building Code, Page* 178.)

Stoves should be set preferably on brick work with no combustible material within 12 inches. If there is any

woodwork nearby it should be protected with metal lath and plaster or sheet metal so as to have a good air space behind it for ventilation. (*See Building Code, Page* 180.)

MISCELLANEOUS FEATURES

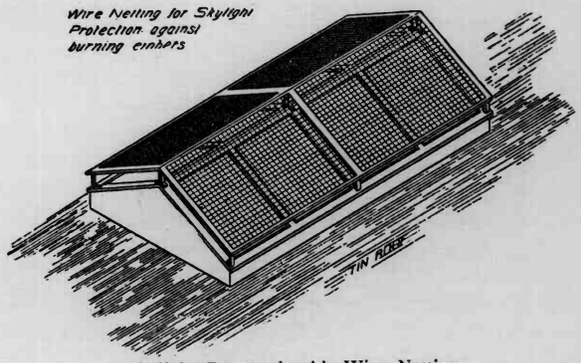
Skylights.—(*See Building Code, Page* 106; *also Skylights.*)

Should be of wired glass or thick glass in metal frames except over standard stair and elevator shafts where thin glass should be used so as to break more quickly and allow a smoke vent. Thin glass should be protected by wire netting where subject to flying embers and brands.

Floor Openings. (*See Building Code, Page* 111.)

The proper shutting off of floor openings is one of the most important features of building construction from a fire protection standpoint. With all openings properly protected the chance that a fire will spread from one floor to another is quite remote, but without such protection the upward spread of fire is probable.

Brick or concrete towers are the best form of enclosure for stairs and elevators and all openings in their walls



Skylight Protected with Wire Netting

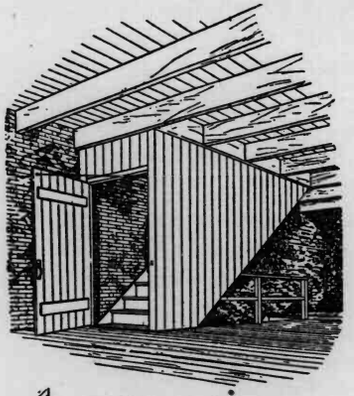


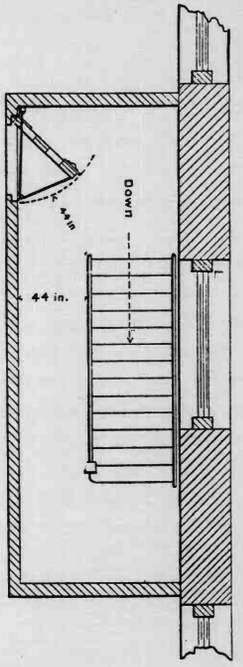
Fig38Stairway Enclosure.

Automatic Trap Door for Stairway

should be protected with fire doors approved for vertical openings. (*See approved list.*)

Curtain boards around unprotected floor openings extending 1 to 2 feet down from the ceiling are of some assistance in preventing rapid spread of fire through openings. They are especially valuable in buildings equipped with sprinklers as they tend to bank up the heat and prevent an excessive number of sprinklers from opening.

Automatic Traps tinned on under side are satisfactory for elevators except where used for passenger service.



Stairway Enclosure (Plan)

Wood Enclosures, if of equal thickness as floor are often acceptable for stairway enclosures. Wooden elevator enclosures form bad flues and where found should be protected on the inside with metal lath and plaster or lock jointed sheet metal.

Chutes and dumb waiters should be similarly enclosed, that is in cut-off tower or lined with fireproof material.

Light Wells are undesirable and cannot be properly guarded.

Cornices.—Where of wood should preferably be open finish. If boxed should be stopped off at intervals so that fire cannot travel along in cornice parallel to wall. (*See Building Code, Page* 106.)

Windows.—(*See Building Code, Page* 108; *Approved List; Fire Door Rules.*)

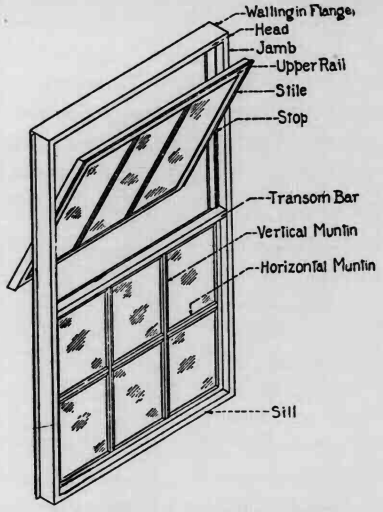
Types.—The principal types of windows are sliding, pivoted, casement, top hinged, tilting and stationary.

Frames.—Frames formed with offsets or shoulders to receive masonry are called rabbeted frames. Frames not provided with rabbets are generally formed with metal wings or flanges. Flanges designed to be built into the masonry are called walling-in flanges. The frames of all windows having a single sash and the frames of sliding sash windows having two sashes are composed of two horizontal members called the head and sill, and two vertical members called the jambs.

That part of the wall structure which divides windows from each other is called the mullion. This mullion may be an intergral part of the wall structure or may be built in with the window.

Sashes.—The horizontal members at the top and bottom of the sash are called the Rails.

The vertical members at the sides of the sash are called the Stiles.



Window Showing Different Parts

The intermediate members, both vertical and horizontal, separating the panes of glass are called Muntins.

Interior Finish.—Wood lath and plaster. Metal lath and plaster. Stamped steel. Plaster boards of various kinds. Mill board. Wood. Varnish finish is bad. Paper and cloth are undesirable. Open finish without sheathing is generally to be preferred.

Concealed spaces should be stopped off at floor level and every 30 feet in floors. Brick or other non-combustible material can be used at floor level. Plank is sometimes used for this purpose. (*See Building Code, Page* 118; *Dwellings, Pages* 73-91.)

Finish may be applied direct to the surface or placed on furring or nailing strips. Furring is undesirable as it causes a hollow space which allows fire to spread in all directions should it get back of the sheathing. It is quite commonly used on the inner side of exterior walls.

Height and Area. (See Building Code, Pages 50-52.) Note requirements as to heights and areas allowed for different types of construction and occupancy.

Means of Egress. (*See Nat'l Board Code, Page* 55.) Proper means of egress is of vital importance from a safety standpoint, but not from a fire protection point of view. All buildings except dwellings less than 3 stories high should have at least two means of exit of sufficient width to accommodate safely all the persons in the building. Exit doors for more than 15 people should open outwards and should not obstruct the passageway when open. Rooms holding over 75 persons should have at least 2 exit doors remote from each other. The minimum width of exits is 44 inches for 50 people and 6 inches extra for each additional 50. Stairways over 7 feet wide should have intermediate continuous hand rail. Winding stairs are undesirable in case of panic. There are special requirements for theatres and schools. (*See Nat'l Board Code, Part XXXV.*)

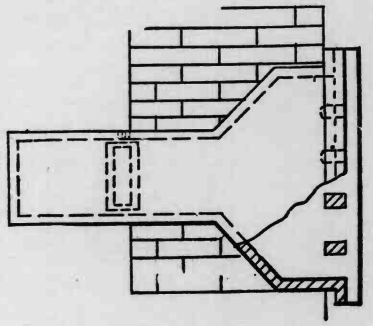
Fire escapes should be non-combustible stairs (not ladders) preferably in cut-off towers. All exposed windows within 10 feet of fire escape should be fire windows or shuttered. Fire escapes to be kept free from storage. Smoke proof towers are the best form of fire escape. Horizontal exits through fire walls into other sections are also acceptable.

Scuppers.—They are installed to carry off water from floors and prevent excessive water loss in case of fire. They are desirable for all buildings but especially in sprinklered buildings and in first class and mill construction. It is desirable to have floors pitch slightly toward the scuppers.

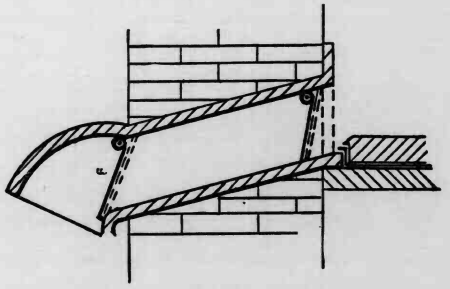
Scuppers may be of the interior type, that is pipes running through the building to some suitable drain or cistern with slotted openings at such floor level; or of the

exterior type set in the outside wall and conducting the water to the outside of the building. In the latter type there should be check valves to prevent cold air from entering the building and they should be protected by vertical bars to prevent clogging. They should be installed so that there is one scupper of 100 gallons per minute capacity for each 500 square feet floor area.

(*See Nat'l Board of Fire Underwriters Pamphlet on Mill Construction*).



Wall Scupper (Top View)



Wall Scupper (Sectional View)

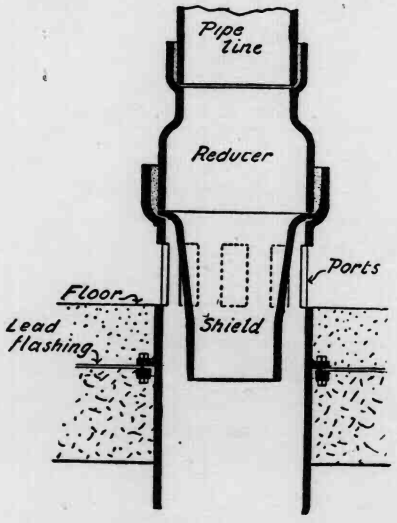
CUT-OFFS

Fire Walls.—(*See Building Code, Page* 44.) A standard cut-off wall is one of brick or concrete 12 inches thick at top and increasing at floors below sufficiently to carry load and be stiff enough to be self supporting. An 8 inch reinforced concrete is considered the full equivalent of a 12 inch brick wall.

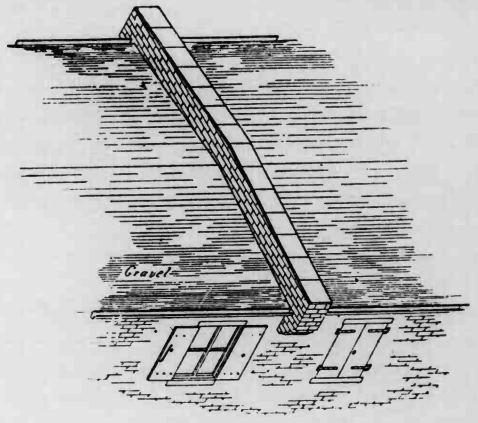
In a frame building such a wall would not usually be self supporting unless abnormally thick or stiffened with pilasters or a tee wall at the end.

Walls should be winged in a building with combustible walls, that is, extended out at right angles to the wall a distance of 5 feet. Or it may be extended 5 feet each way from cut-off wall, along building wall, forming a tee.

Walls should have a 3 foot parapet above roof, pro-



Interior Scupper (Sectional View)



Parapetted Fire Wall

jecting to cut-off over-hang of roof, if any; and with a durable non-combustible coping. No monitor or roof lantern should come near fire wall unless parapet wall is run up to a higher level than same. Where sections are of different height, wall need not be parapetted as much as 3 feet above highest section, but any windows in wall overlooking lower section should be protected with shutters or wired glass as well as those within 10 feet at sides.

In brick buildings, fire wall need not be winged, except to cut off the cornice. There should be no windows for a distance of 10 feet either side of ends of wall or they should be protected with wired glass in metal frames, or standard shutters.

All communicating openings in walls should be protected by standard double fire doors. Shaft openings in fire walls should be protected by standard double doors.

Where the passage is through a stair or elevator well, a single door in each opening to same is generally sufficient.

Where cut-off wall comes at an angle, the windows for a distance of at least 30 feet on one side of the angle should be protected.

Wooden timbers should not enter a fire wall more than one-quarter the thickness of wall and ends should not be nearer to each other than 12 inches at any point.

Fire Doors

(*See Pamphlet of Nat'l Board of Fire Underwriters on Protection of Openings*)

Class A. For Fire Walls.

Double doors are required, that is one each side of opening with air space between. At least one set should be automatic.

Size not to exceed 80 square feet.

Lintel should be brick arch or steel beam fireproofed.

Sill should be non-combustible, that is concrete, masonry or steel plate.

Doors may be of sliding, swinging or rolling type.

Construction of Wood Tin-clad Doors.—Three layers of good tongued and grooved 1 inch boards, planed, and laid with joints broken, nailed with clincher nails. Total thickness not less than 2½ inches.

Tinning.—Prime terne plate I. C., 14 x 20 inches and not less than 113 pounds per box of 112 sheets. Double lock joint ½ inch wide. A hole 3 or 4 inches in diameter on exposed side, over which loose tin may be soldered or nailed, is recommended to let out gases formed in the wood core when door is heated. The out draught of these gases prevents ignition of the wood.

Hardware.—Track, steel 3½ x ⅜ inches inclined ¾ inches to foot. Bolted to wall, bolt opposite each hanger

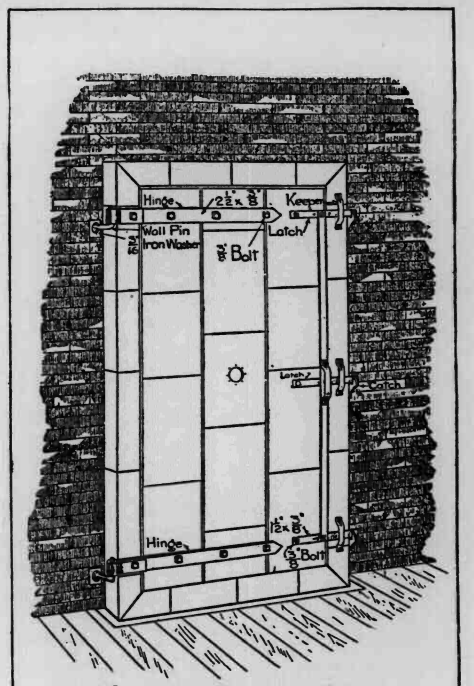


Fig. 23 Swinging Door without Rabbet in wall.

when closed. Also hangers, binders, chafing strips, wedges, bumper shoes, handles, automatic attachments, and in the case of swinging doors, hinges, wall eye, latches and catches are required according to the rules.

Class B.—For doors in stair and elevator towers, single doors allowed. Size not over 8 feet in width and 10 feet high.

Types sliding, swinging, rolling, counter balanced.

Two ply wood core doors allowed. Also metal clad

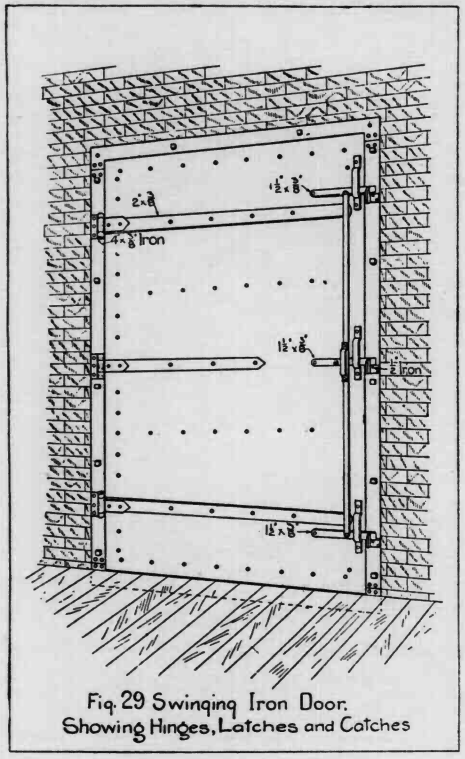


Fig. 29 Swinging Iron Door.
Showing Hinges, Latches and Catches

with panels. Steel, hollow metal, and steel rolling types also approved.

Other requirements similar to those of Class A.

Class C.—For Corridor and Room Partitions.

Two ply tin covered, sheet metal or hollow metal doors with panels. May be hung with butt hinges.

Automatic Devices.—A fusible link operating at 160° F. placed in counter-weight cord is the most usual type.

Link may be at door opening or at ceiling level above doors or both. Devices depending upon the expansion of air or upon a thermostat system are also used and are generally more sensitive.

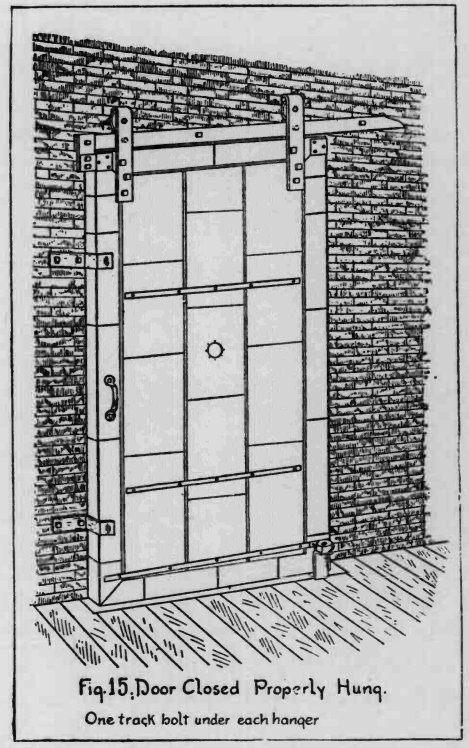


Fig. 15. Door Closed Properly Hung.
One track bolt under each hanger

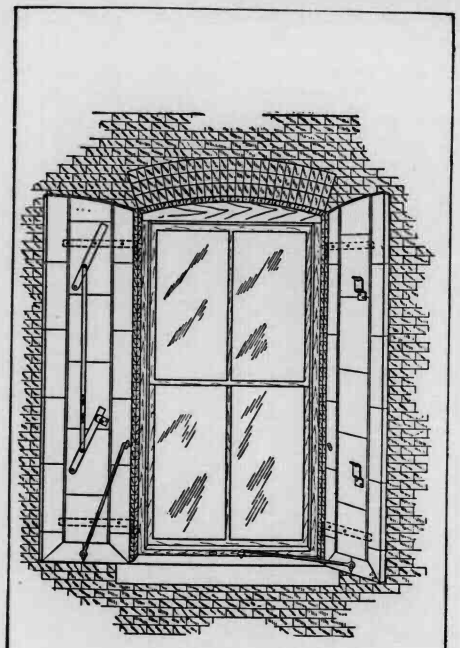


Fig. 31. Tin Clad Fire Shutters.

EXPOSURES

(*See Nat'l Board Building Code, Page* 108, *and Pamphlet on Protection of Openings in Walls; also List of Approved Devices*)

Class D covers tin clad, solid steel and sheet metal shutters; also rolling steel shutters, for protection against severe exposure. Sills and lintels should be non-combustile. *Tin clad* shutters should be made of double boards not less than 1¾ inches total thickness and of

similar construction to a fire door. Tin clad, solid or sheet metal shutters should be not over 10 feet high and of a width not exceeding 4 feet for single or 6 feet for shutters in pairs. They should be equipped with iron hinges 5/16 x 1¾ inches bolted on. These should fit onto cast iron pin blocks set into the wall. There should be at least two latches 1½ x 3/18 inches fitting into catches bolted to shutter.

Rolling steel shutters should not exceed 100 square feet in area and should overlap the top and sides of opening.

Class E covers protection in openings subject to moderate exposure. Here the same rules and devices as specified above apply and in addition wired glass windows with hollow metal frames are allowed. These must not exceed 7 x 12 feet in area and no single pane of glass must exceed 720 square inches.

Frames must be of hollow metal and the glass must be of approved make at least ¼ inch thick set in grooves and embedded preferably in special putty. Windows must be tightly set in masonry and cemented in place.

Class F covers protection of openings subject to light exposure. Here solid metal frame wired glass windows are allowed. The panes should not exceed 54 square inches in area.

Where wired glass windows are used all combustible material should be kept at least 36 inches from the glass as it is liable to be set on fire by heat that radiates through the glass. Guards should be installed where necessary to cover this requirement.

Other Means of Protection.—On wooden buildings, single board wood shutters tinned on the outside and edges are sufficient.

Open sprinklers are also a satisfactory device for protecting against light or moderate exposure. On brick buildings they are located so as to cover all the glass in

each window of the upper floors usually above the first or second floor. In wooden buildings, one or more lines are placed under the eaves and at lower levels depending upon the height of the building and seriousness of the exposure.

Comparison, Shutters and Wired Glass Windows

Tin Clad Shutters.

Advantages.—Transmits heat slower than other forms. Is the best protection when shut and in good repair.

Disadvantages.—Cannot be used on all buildings, especially narrow alleys and street fronts.

Apt to be left open. Often closed with more or less difficulty.

Rather unsightly and expensive to maintain.

Rust quickly around edges and thus expose the woodwork.

Fire inside cannot be seen if shutters are all closed.

Is a fire protection device solely, hence proper attention may not be given.

Wired Glass Windows.

Advantages.—Can be used on all classes of buildings, on all sides or street fronts.

Generally closed. If open can be closed with ease.

Not unsightly.

Practically no maintenance expenses.

Translucent. Windows protected without cutting off light within. Fire within may be discovered from outside.

A distinct part of the building, and apt to be kept in good condition.

Disadvantages.—Transmits heat to a considerable extent.

Cannot withstand very high temperatures without softening.

Recent fires have demonstrated that wire glass is not a positive fire stop in a conflagration. A combination of wired glass with steel shutters or open sprinklers seems to be the best protection for street fronts of office buildings where standard shutters are not practical.

Wired Glass Windows. Asch Building, N. Y.

TIME ALLOWANCE AND RELATIVE IMPORTANCE

Minimum Time Allowance—Eight Hourly Lectures

RELATIVE IMPORTANCE OF SUB-DIVISIONS IN PER CENT

Building Materials	5
Foundations	5
Third Class Construction	10
Second Class, including Mill Construction	15
First Class Construction	20
Roofs	5
Chimneys and Fire Places	5
Miscellaneous	10
Cut-offs	15
Exposure	10

REFERENCES

The first list contains books to which direct reference is made in text and includes publications of the National Board of Fire Underwriters, 76 William Street, N. Y., Underwriters' Laboratories, 207 East Ohio Street, Chicago; and National Fire Protection Association, 40 Central Street, Boston, which may be had free of charge.

Titles in heavy type are the abbreviations referred to in the text.

APPROVED DEVICES: List of Inspected Mechanical Appliances, Underwriters' Laboratories. Revised semi-annually.

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MILL CONSTRUCTION & SCUPPERS: Regulations of National Board of Fire Underwriters. Edition 1918.

ROOF OPENINGS, CORNICES & GUTTERS: Regulations of National Board of Fire Underwriters. Edition 1918.

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U. S. Department of Commerce. Report of Building Code Committee on Recommended Minimum Requirements for Small Dwelling Construction. Washington Government Printing Office 1922.

BUILDING CONSTRUCTION QUESTIONS.

1. What are the three classes of buildings generally specified in building codes?
2. State five non-combustible building materials used for construction, and give their characteristics.
3. Give a short definition of a frame building; ordinary building; mill constructed building; and fireproof building.
4. Give the good and bad points of wood as a building material.
5. Give the principal differences between braced and balloon frame buildings.

6 a. What are the objectionable features of balloon construction?

b. What can be done to improve them?

7. What is a floor opening? Mention not less than six kinds.
8. Why are concealed places objectionable? Mention some kinds.
9. What is a foundation; an independent wall; a party wall; a cornice; a skylight?
10. Describe the principal features of a frame; an ordinary; a mill; and a fireproof building.
11. What features in building construction do you consider most conducive to the spread of fire? State your reason.

12 a. Give the principal building materials in the order of their fire-resisting qualities.

b. Discuss the relative value of wood and steel as a building material from the standpoint of fire protection.

13 a. Under what conditions are concealed spaces in wooden floors particularly undesirable?
b. How can conditions be improved?

14. What is a furred wall? Why is it objectionable from a fire protection standpoint?

15. What protection is essential to the metal work in a fireproof building, and how thick should it be?

16. Describe the principal methods of fireproofing steel, and state the minimum covering necessary.

17. Describe with a sketch the proper construction of a chimney for a private dwelling.

18. Describe the construction of a brick chimney and fireplace.

19. Describe chimney construction for an ordinary dwelling, and illustrate how the beams should be cut away where the chimney passes through the floor.

20. How can sheathing on walls and floors be made acceptable from a fire protection standpoint?

21. Describe the construction of outside walls in two types of fireproof buildings.

22. Describe the main features of a "mushroom" type concrete building.

23. State how a skylight should be built in a congested district.

24. What kind of skylight should be used at the top of a standard elevator shaft?

25 a. Describe a mansard roof.
b. Why is it objectionable?

26. State how the Underwriters' laboratories classify roof coverings.

27. Describe 3 ways of enclosing stairways.

28. What is a standard enclosure for stairways; elevators; dumb waiter shafts?

29 a. Mention several different roof coverings that are approved.
b. State what type of roof covering you consider the most objectionable, and why.

30. How should steel columns be protected against heat?

31. Describe two types of fireproof floors.

32. What are the more important types of fire doors? Describe the construction of one type.

33. Give the more essential features of a standard automatic tin-covered fire door.

34. What floor openings should be protected in a fireproof building? How should it be done?

35. Describe how to build a standard fire wall in a frame building.

36. How should a parapet be built on a fire wall in a brick building with wooden cornice?

37 a. Where two buildings adjoin and communicate, how would you protect the openings?
b. What type of door would you recommend?

38. What are the methods of protecting exposed windows?

39 a. How is a scupper built?
b. How is it installed?

40. What features of mill construction are apt to be built in a sub-standard manner?

41. What are the practical methods of protecting the windows in a fireproof office building against a heavy conflagration exposure? Give the weakness of each.

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